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Sagona

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(54) **OVERVOLTAGE PROTECTION UNIT WITH AC INPUT CURRENT SENSORS**

(71) Applicant: **Hamilton Sundstrand Corporation**, Windsor Locks, CT (US)

(72) Inventor: **John Duward Sagona**, Poplar Grove, IL (US)

(73) Assignee: **Hamilton Sundstrand Corporation**, Windsor Locks, CT (US)

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H02H 7/125	(2006.01)
H02H 9/04	(2006.01)
H02H 3/05	(2006.01)

(52) **U.S. Cl.**

CPC ***H02H 7/1252*** (2013.01); ***H02H 9/04*** (2013.01); ***H02H 9/041*** (2013.01); *H02H 3/05* (2013.01)

(58) **Field of Classification Search**

USPC 323/34–38, 78, 84, 89, 124–127; 363/34–38, 78, 84, 89, 124–127

See application file for complete search history.

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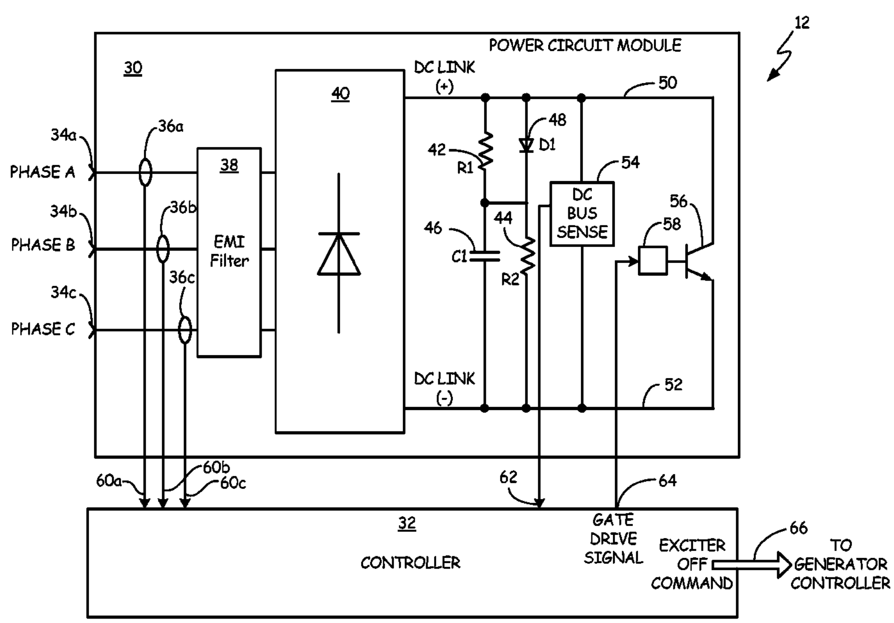
Primary Examiner — Jeffrey Gblende

(74) *Attorney, Agent, or Firm* — Kinney & Lange, P.A.

(57) **ABSTRACT**

An overvoltage protection unit includes a power circuit module and a controller module. The power circuit module receives power from a power source on an AC input and includes a rectifier that converts voltage on the AC input into a DC Link output voltage, and an AC input current sensor that senses a current on the AC input. The controller module provides an output to terminate power from the power source based upon the DC Link output voltage and a sensed current from the AC input current sensor.

15 Claims, 2 Drawing Sheets



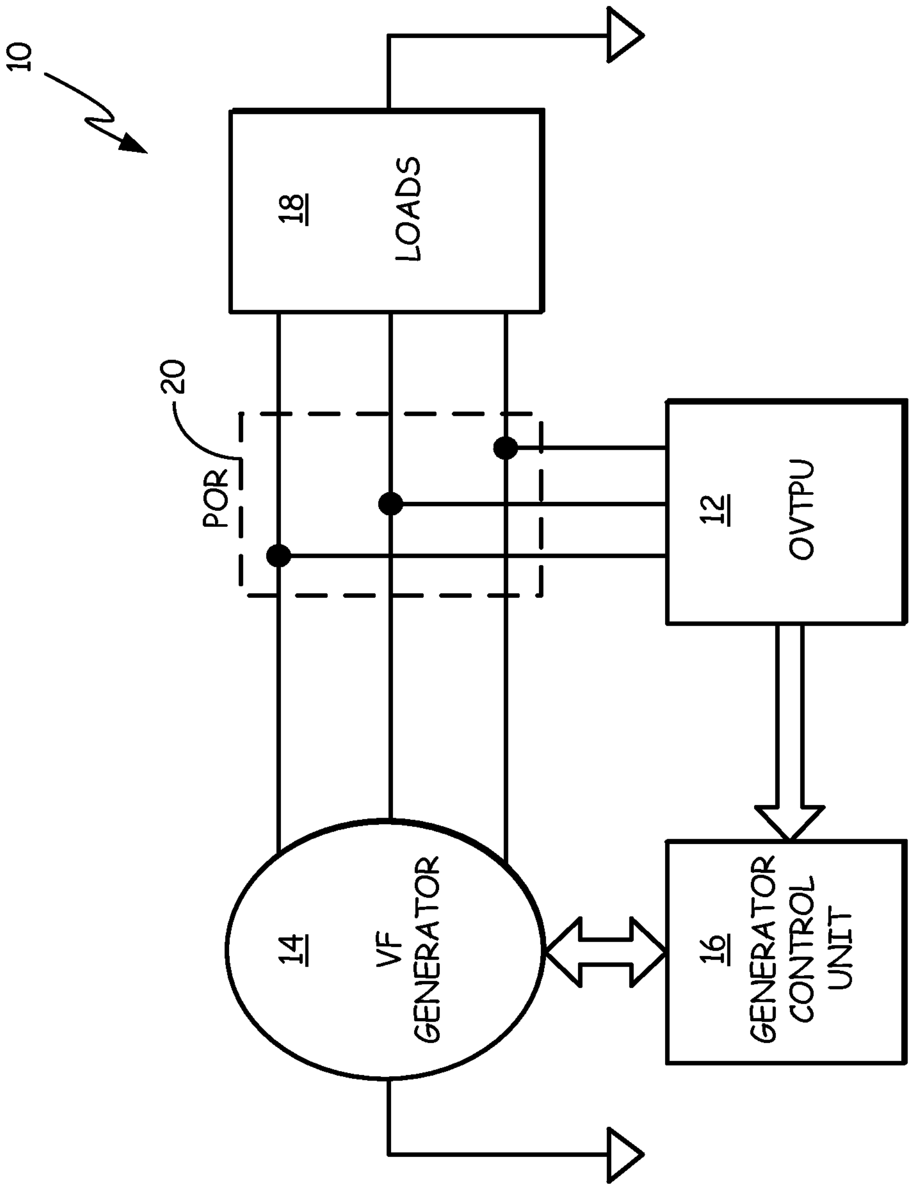

10
18
LOADS
20
POR
12
OVTPU
14
VF
GENERATOR
16
GENERATOR
CONTROL
UNIT

FIG. 1

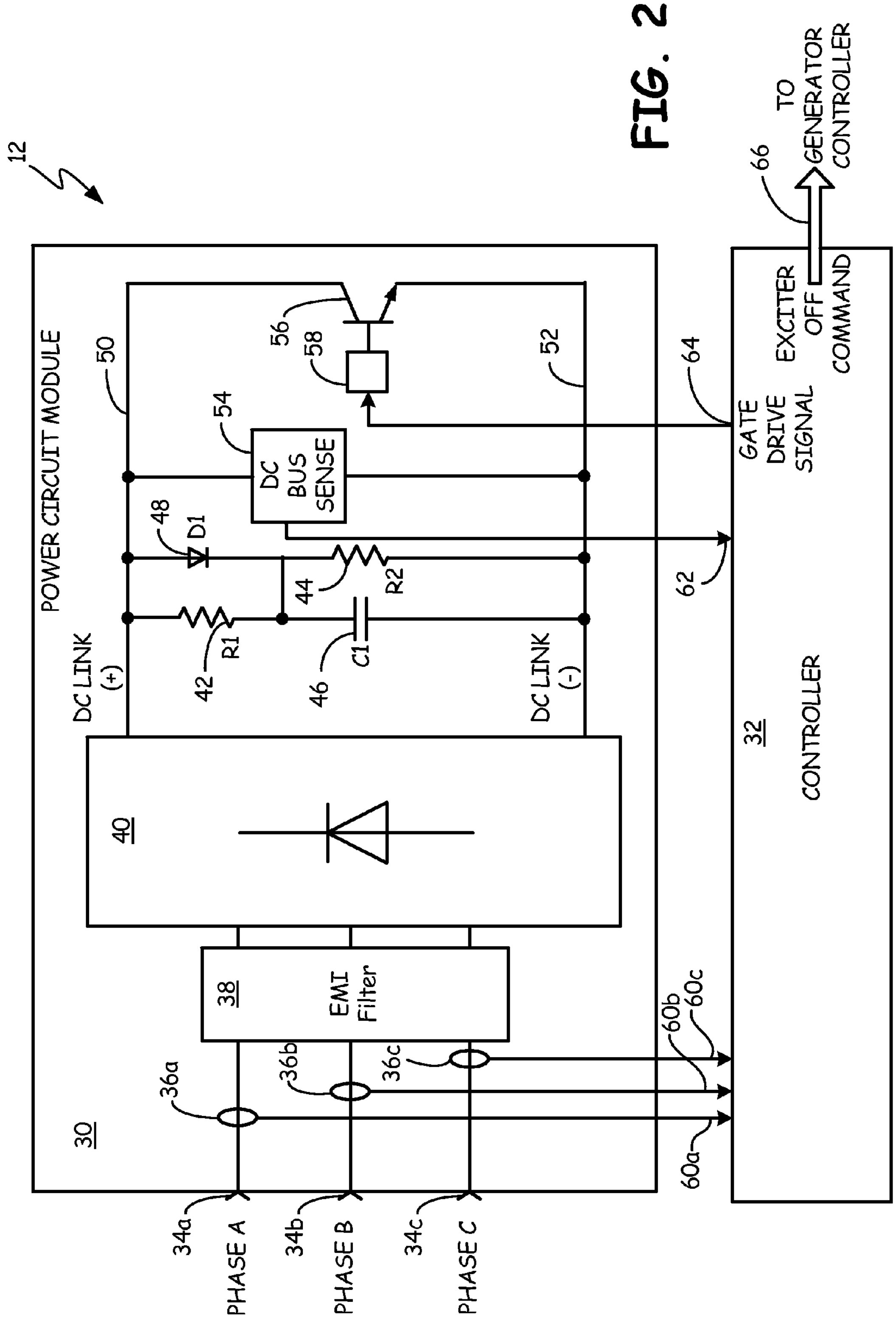

12
POWER CIRCUIT MODULE
30
50
52
54
DC BUS SENSE
56
58
48
D1
44
R2
42
R1
46
C1
DC LINK (+)
DC LINK (-)
40
38
EMI Filter
36a
36b
36c
34a
34b
34c
PHASE A
PHASE B
PHASE C
60a
60b
60c
62
64
GATE DRIVE SIGNAL
66
EXCITER OFF COMMAND
TO GENERATOR CONTROLLER
32
CONTROLLER

FIG. 2

OVERVOLTAGE PROTECTION UNIT WITH AC INPUT CURRENT SENSORS

BACKGROUND

Electrical systems, such as those of an aircraft, may include variable frequency (VF) generators for power generation. These generators often include generator controllers that monitor and control the operation of the generator. In addition to the generator controller, these electrical systems often include overvoltage protection units that monitor voltage at a second point of protection.

Generator controllers, commonly referred to as generator control units (GCUs), regulate the operation of associated generators. For example, the GCU monitors the output voltage of the generator and regulates the current supplied to the exciter winding to regulate the output voltage to a desired value. In addition, the GCU provides protection against faults such as overvoltage faults. For example, if the circuit used to regulate the current supplied to the exciter winding fails, the GCU may trip a relay to disconnect power from the exciter winding, and may trip another relay to disconnect the generator output from a distribution bus to protect devices and components connected thereto.

SUMMARY

An overvoltage protection unit includes a power circuit module and a controller module. The power circuit module receives power from an AC power source on an AC input. The power circuit module includes a rectifier that converts voltage on the AC input into a DC Link voltage, and an AC input current sensor that senses a current on the AC input. The controller module provides an output to terminate power from the power source based upon the DC Link voltage and a sensed current from the AC input current sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating an electrical power system that includes overvoltage protection.

FIG. **2** is a circuit diagram illustrating an overvoltage protection unit that includes internal fault protection.

DETAILED DESCRIPTION

The present invention relates to power systems, and in particular to an overvoltage protection system for a variable frequency (VF) generator. An overvoltage transient protection unit (OVTPU) includes both overvoltage protection for loads, as well as internal fault protection of the OVTPU itself. The OVTPU converts an AC three-phase input into a DC Link voltage. The OVTPU monitors the DC Link voltage to determine if it is greater than a threshold value. If it is, then the OVTPU provides a termination signal to a generator control unit (GCU) in order to terminate power from the VF generator. The OVTPU also includes three AC input current sensors on the three AC inputs. These current sensors monitor each input line to determine if the current is greater than a threshold value. If any line contains too great of a current, the OVTPU sends a terminate signal to the GCU. This provides protection against faults, such as short circuit faults, within the OVTPU itself that would otherwise go undetected by the OVTPU.

FIG. **1** is a block diagram illustrating electrical power system **10** with redundant overvoltage protection. System **10** includes OVTPU **12**, VF generator **14**, generator control unit (GCU) **16**, loads **18**, and point of regulation (POR) **20**. VF generator **14** is any generator such as, for example, a generator of an aircraft driven by a gas turbine engine. GCU **16** may be used to, among other things, regulate the operation and output of VF generator **14** using any known method. Loads **18** are any loads that receive power from VF generator **14** such as, for example, avionics systems of an aircraft.

In the present embodiment, OVTPU **12** monitors voltage at POR **20**. Three inputs are provided to OVTPU **12**, one for each phase of the three-phase output from VF generator **14**. OVTPU **12** monitors for overvoltage events caused by, for example, load removal or arc faults. If OVTPU **12** detects an overvoltage, it sends a terminate signal to GCU **16**. GCU **16** terminates power from VF generator **14** upon receiving this signal. OVTPU **12** may also provide a temporary low impedance path to dissipate energy generated by VF generator **14** when an overvoltage is detected at POR **20**.

FIG. **2** is a circuit diagram illustrating OVTPU **12** that includes internal fault protection. OVTPU **12** includes power circuit module **30**, and controller module **32**. Power circuit module **30** includes three-phase inputs **34***a*-**34***c*, current sensors **36***a*-**36***c*, electromagnetic interference (EMI) filter **38**, rectifier **40**, resistors **42** and **44**, capacitor **46**, diode **48**, DC line **50**, return path **52**, voltage sense device **54**, switch **56**, and gate driver **58**. Controller module **32** includes current sensor inputs **60***a*-**60***c*, voltage sense input **62**, gate drive output **64**, and exciter-off output **66**. Switch **56** is any known electronic switch such as, for example, an insulated gate bipolar transistor (IGBT). Controller module **32** may be implemented as, for example, a plurality of integrated circuits, a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), or any other digital logic circuit.

Power circuit module **30** monitors voltage and provides a low impedance path to return path **52** in the event of a detected overvoltage. Inputs **34***a*-**34***c* provide AC three-phase voltage to OVTPU **12** from POR **20** of FIG. **1**. Current sensors **36***a*-**36***c* sense current on each of respective inputs **34***a*-**34***c*. The sensed current values are provided to controller module **32** on inputs **60***a*-**60***c*. Current sensors **36***a*-**36***c* are any known sensors capable of sensing an electric current.

The voltage on inputs **34***a*-**34***c* is filtered by EMI filter **38**, and rectified by three-phase rectifier **40** to generate a DC output voltage on DC line **50**. EMI filter **38** is any known EMI filter and is, for example, connected to a ground such as the chassis of an aircraft. Rectifier **40** is any known rectifier capable of rectifying a three-phase AC input into a DC output such as, for example, a six bridge rectifier. Capacitor **46** is charged through diode **48**. Once capacitor **46** is charged, power module **30** draws a minimal amount of power from inputs **34***a*-**34***c*.

During normal operation, switch **56** is off, and does not conduct between DC line **50** and return path **52**. Voltage sense device **54** senses the voltage between DC line **50** and return path **52** and provides a sensed voltage to controller module **32** on input **62**. Voltage sense device **54** may be implemented as, for example, a differential amplifier or any other known device capable of sensing a voltage. Controller module **32** monitors the sensed voltage to determine if an overvoltage condition is present. Resistor **44** is implemented to discharge capacitor **46** when the system is not in use so that capacitor **46** does not remain charged during, for example, maintenance.

In response to a detected overvoltage condition, switch **56** is turned on to create a low-impedance path between DC line **50** and return line **52**. Controller module **32** detects an overvoltage condition using the sensed value on input **62**. If this value is greater than a threshold value, controller module **32** provides an output on output **64** to gate driver **58**. Switch **56** is turned on and begins conducting between DC line **50** and return path **52**. Capacitor **46** discharges through resistor **42**, and power is circulated through switch **56** and rectifier **40** on DC line **50** and return path **52**. This dissipates a large amount of energy provided by the VF generator across switch **56**. To prevent damage to power module **30**, controller module **32** also provides an output on exciter-off output **66**. This output is received by GCU **16** of FIG. **1**. GCU **16** terminates power from VF generator **14** of FIG. **1** upon receiving this signal. This way, switch **56** is only turned on for a short amount of time, to temporarily dissipate the energy produced by VF generator **14** while GCU **16** is de-exciting VF generator **14**.

The current on inputs **34***a*-**34***c* is monitored by controller module **32** to determine if there is a fault within OVTPU **12**. This fault may be, for example, a short circuit fault within any of the electronics of OVTPU **12**, or any other fault that causes a large current draw on any of inputs **34***a*-**34***c*. This fault would not cause an overvoltage on positive DC line **50**, and thus, OVTPU **12** would not detect this fault without input current sensors **36***a*-**36***c*.

Upon detection of an over-current condition on any of inputs **34***a*-**34***c*, controller module **32** provides an output on exciter-off output **66** to terminate power from VF generator **14** of FIG. **1**. Controller module **32** receives a sensed current from each current sensor **36***a*-**36***c* on inputs **60***a*-**60***c*. If any of the sensed values on these inputs **60***a*-**60***c* are greater than a threshold value, controller module **32** detects a fault and provides a terminate signal to the GCU on output **66**. This output is received by GCU **16** of FIG. **1**. GCU **16** terminates power from VF generator **14** of FIG. **1** upon receiving this signal. Short circuit faults within OVTPU **12** can lead to large and undesirable power draws from VF generator **14**. By detecting faults within OVTPU **12** and terminating power from VF generator **14**, large power losses and negative affects on the circuits can be avoided.

The following are non-exclusive descriptions of possible embodiments of the present invention.

An overvoltage protection unit includes, among other things: a power circuit module that receives power from a power source on an AC input, and a controller module. the power circuit module includes a rectifier that converts voltage on the AC input into a DC Link output voltage, an AC input current sensor that senses a current on the AC input. The controller module provides an output to terminate power from the power source based upon the DC output voltage and a sensed current from the AC input current sensor.

The overvoltage protection unit of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:

The AC input is a three-phase AC input.

The controller module provides the output to terminate power if the sensed current from the AC input current sensor is greater than a first threshold value.

The controller module provides the output to terminate power if the DC Link output voltage is greater than a second threshold value.

The power circuit module further includes an electromagnetic interference filter that filters electromagnetic interference on the AC input.

The power circuit module further includes a switch, wherein the switch is enabled to provide a low impedance path between the DC Link output voltage and a return path.

The controller module enables the switch if the DC Link output voltage is greater than a threshold value.

A system includes, among other things: a generator that produces three-phase AC power for a load, and an overvoltage protection unit that monitors the three-phase AC power on three AC inputs. The overvoltage protection unit includes a power circuit module and a controller module. The power circuit module includes a rectifier that converts AC voltage on the three AC inputs into a DC Link voltage, and three current sensors that sense a current on each of the three AC inputs. The controller module terminates power from the generator based upon the DC Link voltage and sensed current from the three current sensors.

The system of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:

A generator control unit that controls output of the three-phase power from the generator. The controller module terminates power from the generator by sending a terminate signal to the generator control unit.

The controller module sends the terminate signal if the DC Link voltage is greater than a first threshold value, or a sensed current from one of the three current sensors is greater than a second threshold value.

The power circuit module further includes a switch. The switch is enabled to provide a low impedance path between the DC Link voltage and a return path if the DC Link voltage is greater than the first threshold value.

The power circuit module further includes an electromagnetic interference filter that filters electromagnetic interference on the three AC inputs.

A method of overvoltage protection includes, among other things: providing AC power from a generator to an overvoltage protection unit on an AC input, monitoring current on the AC input using a current sensor, converting the AC input into a DC Link output using a rectifier, monitoring the DC Link output using a voltage sense device, and terminating power from the generator if a monitored voltage from the voltage sense device is greater than a first threshold value, or if a monitored current from the current sensor is greater than a second threshold value.

The method of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:

Terminating power from the generator includes sending a terminate signal to a generator control unit.

Filtering the AC power includes using an electromagnetic interference filter.

A low impedance path for the DC Link output is provided if the monitored voltage from the voltage sense device is greater than the first threshold value.

Providing a low impedance path includes enabling a switch between the DC Link output and a return path if the monitored voltage from the voltage sense device is greater than the first threshold value.

The AC power is three-phase AC power.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

The invention claimed is:

1. An overvoltage protection unit comprising:

a power circuit module that receives power from a power source on an AC input, the power circuit module comprising:

a rectifier that converts voltage on the AC input into a DC Link output voltage;

an AC input current sensor that senses a current on the AC input; and a switch;

a controller module that provides an output to terminate power from the power source based upon the DC Link output voltage and a sensed current from the AC input current sensor, wherein the controller module detects a first fault external to the overvoltage protection unit based upon the DC Link output voltage and detects a second fault internal to the overvoltage protection unit based upon the AC input current sensor; and wherein the switch is enabled to provide a low impedance path between the DC Link output voltage and a return path to circulate current through the rectifier until the power from the power source is terminated.

2. The overvoltage protection unit of claim 1, wherein the AC input is a three-phase AC input.

3. The overvoltage protection unit of claim 1, wherein the controller module provides the output to terminate power if the sensed current from the AC input current sensor is greater than a first threshold value.

4. The overvoltage protection unit of claim 3, wherein the controller module provides the output to terminate power if the DC Link output voltage is greater than a second threshold value.

5. The overvoltage protection unit of claim 1, wherein the power circuit module further comprises an electromagnetic interference filter that filters electromagnetic interference on the AC input.

6. The overvoltage protection unit of claim 1, wherein the controller module enables the switch if the DC Link output voltage is greater than a threshold value.

7. A system comprising:

a generator that produces three-phase AC power for a load;

an overvoltage protection unit that monitors the three-phase AC power on three AC inputs, the overvoltage protection unit comprising:

a power circuit module comprising a rectifier that converts AC voltage on the three AC inputs into a DC Link voltage, a switch and three current sensors that sense a current on each of the three AC inputs; and

a controller module that terminates power from the generator based upon the DC Link voltage and sensed current from the three current sensors, wherein the controller detects a first fault external to the overvoltage protection unit based upon the DC Link voltage and detects a second fault internal to the overvoltage protection unit based upon the three current sensors; and wherein the switch is enabled to provide a low impedance path between the DC Link voltage and a return path if the DC Link voltage is greater than a first threshold value to circulate current through the switch and the rectifier until the three-phase AC power from the generator is terminated.

8. The system of claim 7, further comprising a generator control unit that controls output of the three-phase power from the generator, wherein the controller module terminates the three-phase AC power from the generator by sending a terminate signal to the generator control unit.

9. The system of claim 8, wherein the controller module sends the terminate signal if the DC Link voltage is greater than the first threshold value, or a sensed current from one of the three current sensors is greater than a second threshold value.

10. The system of claim 7, wherein the power circuit module further comprises an electromagnetic interference filter that filters electromagnetic interference on the three AC inputs.

11. The system of claim 7, wherein the power circuit module further comprises:

a first circuit comprising a capacitor connected in parallel with a first resistor;

a second circuit comprising a diode connected in parallel with a second resistor, wherein the first circuit is connected in series with the second circuit, and wherein the DC Link output voltage is sensed across the first circuit and the second circuit;

wherein the capacitor discharges through the first resistor when the system is not in use; and

wherein the capacitor discharges through the second resistor when the switch is enabled.

12. A method of overvoltage protection, the method comprising:

providing AC power from a generator to an overvoltage protection unit on an AC input;

monitoring current on the AC input using a current sensor;

converting the AC input into a DC Link output using a rectifier;

monitoring the DC Link output using a voltage sense device;

detecting a first fault external to the overvoltage protection unit if a monitored voltage from the voltage sense device is greater than a first threshold value;

detecting a second fault internal to the overvoltage protection unit if a monitored current from the current sensor is greater than a second threshold value;

terminating power from the generator if the first fault or the second fault are detected; enabling a switch between the DC Link output and a return path if the monitored voltage from the voltage sense device is greater than the first threshold value; and circulating power through the switch and the rectifier until the power from the generator is terminated.

13. The method of claim 12, wherein terminating power from the generator comprises sending a terminate signal to a generator control unit.

14. The method of claim 12, further comprising filtering the AC power using an electromagnetic interference filter.

15. The method of claim 12, wherein the AC power is three-phase AC power.

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